PRELIMINARY LEACHATE AND GAS MIGRATION STUDY DUNDAS LANDFILL SITE

FOR

REGIONAL MUNICIPALITY OF HAMILTON-WENTWO

GARTNER LEE ASSOCIATES LIMITED

Gartner Lee Associates Limited

Consulting Engineering Geologists and Hydrogeologists

Toronto-Buttonville Airport ■ Markham, Ontario ■ L3P 3J9 ■ 416-297-4600

PRELIMINARY LEACHATE AND GAS MIGRATION STUDY DUNDAS LANDFILL SITE

FOR

REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

PROJECT NO: 79-25

JULY, 1979

DISTRIBUTION:

12 cc: CLIENT

1 cc: FILE

Gartner Lee Associates Limited

Consulting Engineering Geologists and Hydrogeologists

Toronto-Buttonville Airport ■ Markham, Ontario ■ L3P 3J9 ■ 416-297-4600

July 26, 1979.

Regional Municipality of Hamilton-Wentworth,
Department of Engineering,
City Hall, 6th Floor,
Hamilton, Ontario.
L8N 3V9

Attention: Mr. W. Wheton, P.Eng.,
Commissioner of Engineering.

Dear Sirs:

RE: Preliminary Leachate and Gas Migration Study
Dundas Landfill Site

We are pleased to submit our report that deals with the preliminary leachate and gas migration study of the Dundas Landfill Site. The assignment was authorized by the Region on March 19, 1979, under purchase order number R28858. The text of the report documents (A) the terms of reference, (B) the methodology, (C) the study findings and discussion. Conclusions and recommendations for both leachate and gas aspects are presented for your consideration. Background data is appended.

A. TERMS OF REFERENCE

An arena, the Dundas Olympic Ice Facility was constructed to the west and south of the Dundas Landfill Site which is presently closed. Gas was detected in the area around and in the arena itself last year and this problem was investigated by others. Recommendations of that investigation provided for a passive gas venting system

adjacent to the structure. The Region subsequently expressed concern regarding the affect of the entire waste disposal site on the surrounding environs and the need for control and monitoring on the landfill site itself.

The present study was then initiated to assess both leachate and gas migration aspects as they pertain to the landfill site as a whole and as related to the total controls or remedial work which may be required. Specifically the purposes of the preliminary study are a) to identify any potential problems b) to assess their scope and c) to determine the necessity for detailed hydrogeological/geotechnical investigations, associated with the waste. Thus the preliminary study is of feasibility and planning nature.

B METHODOLOGY

The preliminary assessment was carried out using an integration of office analysis procedures and field investigation techniques. A conceptual hydrogeological model of the site and its environs was constructed in the office from data obtained from the following sources: Ministry of the Environment water well records; published geological maps and reports; and existing reports such as the Heath Survey Consultants' report on gas migration at the arena, the William Trow Associates' foundation report for the arena, and the Peto Associates' soils report for Olympic Drive. As well, aerial photographs from the three time periods 1954, 1972 and 1978 were stereoscopically interpreted to provide details of the location and extent of the waste as historically recorded on the photographs and of the geologic setting. These data were plotted on a derived base map at a scale of 1" = 200'.

The site was then field checked to verify office interpretations and geologically field mapped to show

such features as leachate springs and drainage conditions. As well, the upper soils around the periphery and within the immediate environs of the site were checked for the presence of gas using a standard gas probe. See map 1, 'Site Plan' for the location of all hand auger holes and gas checks, and the Appendix for detailed results. There was no sub-surface drilling due to the feasibility and planning nature of the study.

Finally all data were collated and analysed, and an engineering report prepared to document the findings.

C. STUDY RESULTS

1. PHYSICAL SETTING: The Dundas Landfill Site is situated in the lower portion of the Dundas Valley and adjacent to Cooies Paradise. The immediate area is veneered by sands and gravels up to 15 feet deep over a glacial till, while the lands south and west appear to be infilled with soft lacustrine clays. The deeper granular soils are associated with a beach bar land form extending approximately north-south through the area. See map 2, 'Physical Setting' for details. Based on the historical airphotos, the granular soils were locally extracted. These pits then formed the original fill areas.

   From soil borings by others (see the Appendix for pertinent details), there appears to be an unconfined ground water system perched within the granular soils. The water table varies depending upon the topography and thickness of the granular horizon but may be upwards to 15 feet below ground surface. Since ground water flow is expected to be generally a subtle reflection of the surface topography, there may be a ground water divide associated with the beach bar. Ground water would in that case flow

LEGEND

- ●25 Hand Auger Hole & Combustible Gas Probe (Gartner Lee Assoc. Ltd., Mar. 1979)
- ■4 Borehole (Trow Assoc., Nov. 1974)
- ⊕2 Borehole (Heath Survey Consultants Ltd Jan 1979)
- ▲20 Borehole (Peto Assoc. Ltd., Jan. 1973)
- Dundas Landfill Property Boundary
- Open Water
- Original Contours Altered By Filling and Grading
- Culvert
- Hydro Transmission Tower
- Building

NOTE Borehole and hand auger hole locations are not surveyed and may vary from the locations shown

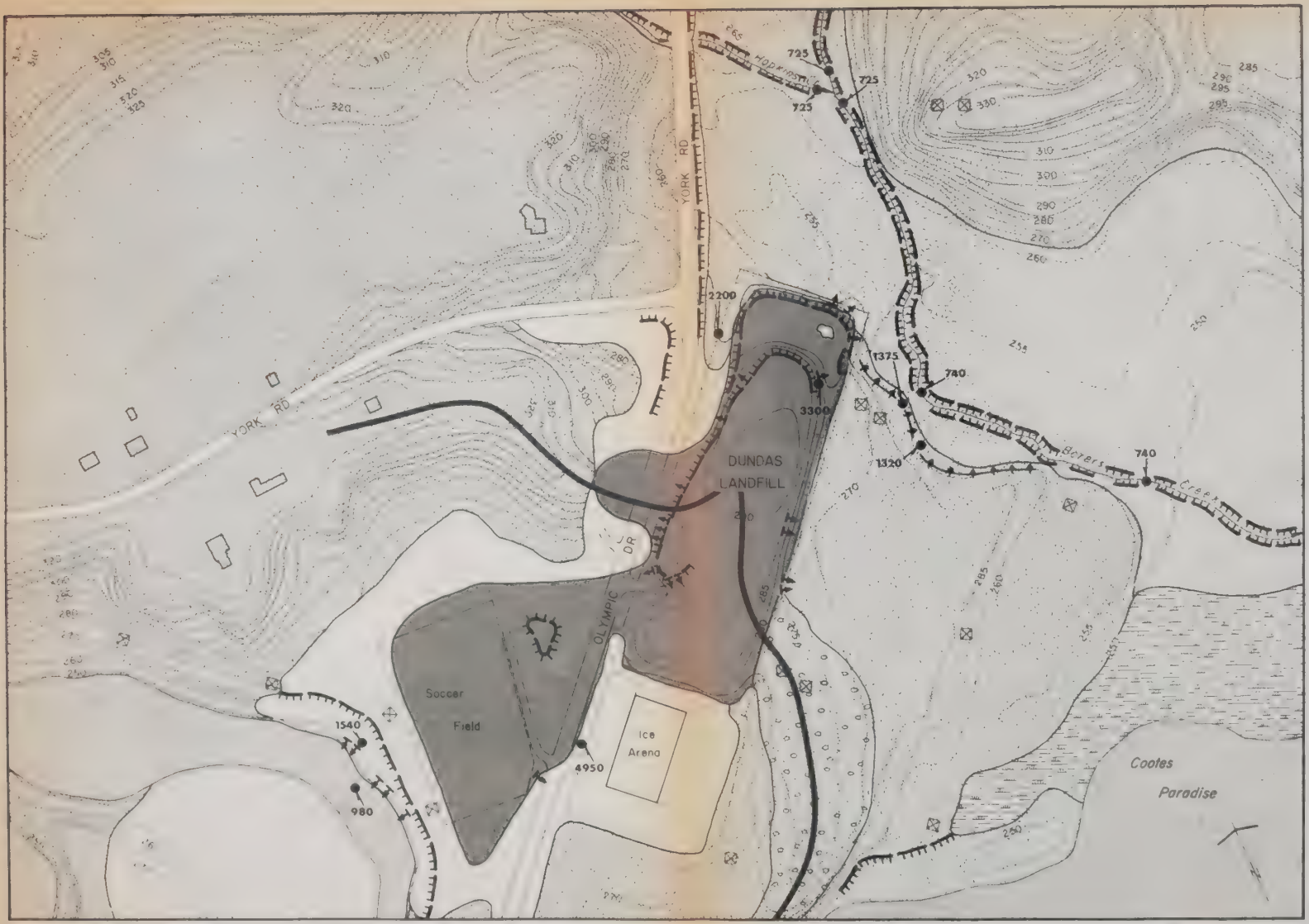
NOTE Base map derived by Gartner Lee Assoc Ltd from 1959 contour mapping, 1979 landfill contours and existing site condition No field survey control

SITE PLAN 1

Preliminary Leachate and Gas Migration Study, Dundas Landfill
for
Regional Municipality of Hamilton-Wentworth

Project 79-25
Scale 1 in. to 200 ft.
feet

Gartner Lee Associates Limited



LEGEND

- Shallow Sands & Gravel Over Till
- Beach Bar
- Earth Fill
- Refuse
- Alluvial Soils
- Organics
- Open Water
- Steep Slope
- Leachate Springs
- Seepage
- 1320 Water Conductivity in umhos/cm.
- Approximate Surface Water Divide

NOTE Base map derived by Gartner Lee Assoc. Ltd. fr... 1959 contour mapping 1979 landfill contours and existing site condition. No field survey control.

PHYSICAL SETTING 2

Preliminary Leachate and Gas Migration Study, Dundas Landfill

for

Regional Municipality of Hamilton-Wentworth

Project 79-25

Scale 1 in. to 200 ft

feet 100 0 100 200

Gartner Lee Associates Limited

both towards the creek and to the pond to the west of the site. Springs were noted at the sand-till interface along the banks of the creek. Due to the lack of control points, however, a detailed analysis of the ground water regime is not feasible at this stage. There is no recorded ground water use in the area of the landfill.

Hydrologically, the site is situated between two drainage basins - the Desjardin Canal and Borers Creek - both of which discharge into the western end of Hamilton Harbour. The head waters of Borers Creek are located on lands above the Niagara Escarpment, in the vicinity of Highway 5, and the total length of the creek is about 4 miles. Although water flow is perennial, at least through the lower reaches of the creek, no recorded flow data is available. Surface water uses were not documented for this study. However, it is known that the lands and waters within the western portions of Hamilton Harbour form part of the Botanical Gardens and that Cootes Paradise in particular is an environmentally sensitive area.

The conductivity, which is a measure of the total concentration of ions in solution, was measured in Borers Creek upstream and downstream of the landfill. The readings showed a slight increase from 725 to 740 micro mhos per centimeter.

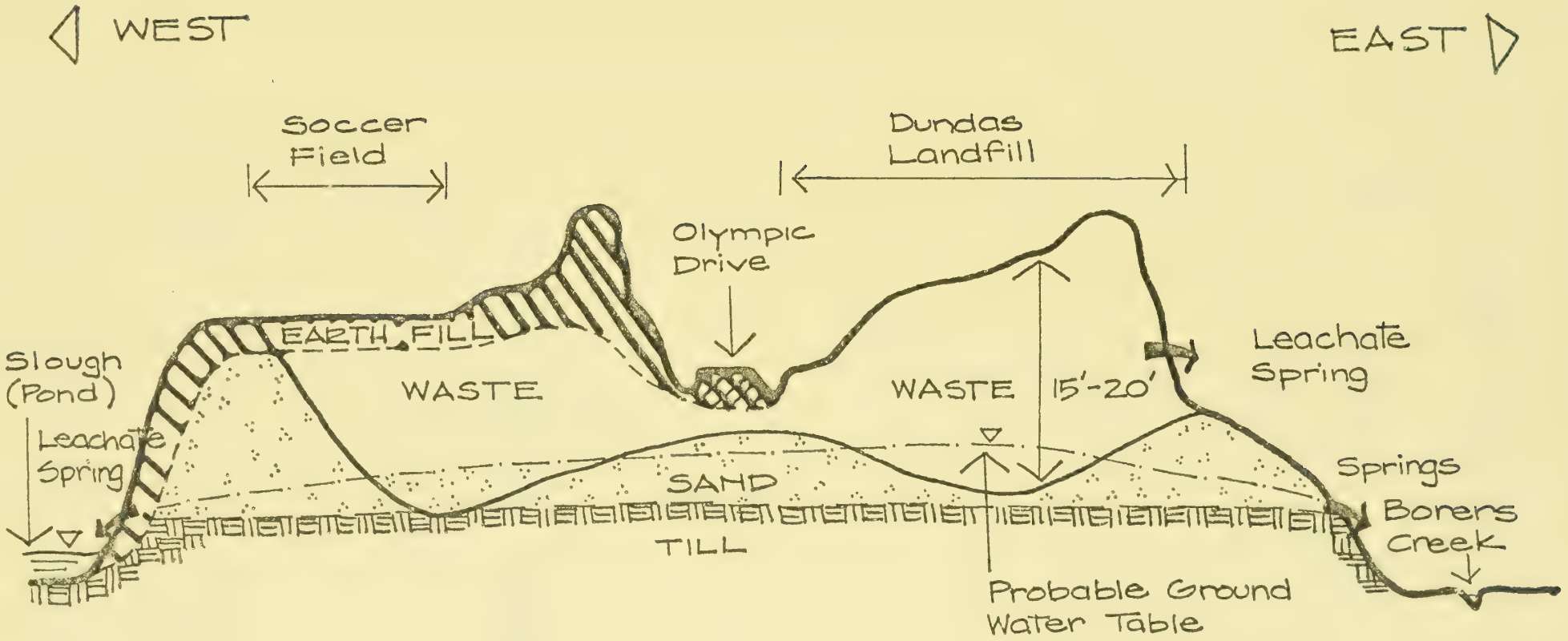
II LANDFILL SITE: Based on all available data and our geological field reconnaissance survey, the area of waste disposal was delineated and is shown on map 2, 'Physical Setting'. Waste extends beyond the lands formally designated the Dundas Landfill Site, with a significant zone to the west. The waste was originally disposed of in former gravel pits, but may have subsequently included natural ground. Boreholes drilled by others indicate that the waste may be in the order of 15 to 20 feet deep maximum. Only nominal soil cover was observed on the Dundas Landfill Site itself; however there appears to be 3 to 5 feet of clay cover in the area of the

soccer field. A portion of Olympic Drive was constructed over the waste. See Schematic Section 1 for a conceptual view of the hydrogeologic setting in a west to east direction.

Ground water mounding in the waste is probably minimal, being perhaps confined at least seasonally to the deeper sections, due to the permeable nature of the granular soils within which the waste is buried and the local ground water system. Leachate springs however were noted both around the periphery and within the landfill itself. These springs may reflect a perched water condition related possibly to local zones of less permeable waste and/or of daily clay cover. As well there are leachate springs emanating at the base of the slope adjacent to the pond and along the west bank of Borers Creek. The conductivity of these springs was in excess of 1000 micro mhos per centimeter.

Gas was detected both in the waste and within the immediate environs. The distribution of combustible gas in May 1979 is shown on map 3 entitled 'Combustible Gas Distribution'. As reported by others gas has migrated off-site towards the Dundas Olympic Ice Facility, and is of concern to the facility. The migration of gas appears to be more significant in the area of the soccer field, possibly a result of the clay cover, than in the landfill site itself which has less cover material.

III WATER BUDGET: The water budget for this site was calculated from climatological data at a weather recording station in Hamilton. For the determination of the potential evapotranspiration, the Thornthwaite method of analysis was employed. Following is a summary of the results presented in Table 1 of the appendix:



Schematic Section 1

(NOT TO SCALE)

LEGEND

- Approximate Distribution of Combustible Gas (May, 1979)
- Extent of Fill Underlain By Refuse
- 30% Combustible Gas

NOTE: Base map derived by Gartner Lee Assoc. Ltd. from 1959 contour mapping, 1979 landfill contours and existing site condition. No field survey control.

COMBUSTIBLE GAS DISTRIBUTION

3

Preliminary Leachate and Gas Migration Study, Dundas Landfill

for

Regional Municipality of Hamilton-Wentworth

Project 79-25

Scale 1 in. to 200 ft.

100 0 feet 100 200

Gartner Lee Associates Limited

Average Annual Mean Precipitation	31.2 inches
Average Annual Potential Evapotranspiration	25.0 inches
Average Annual Potential Surplus	6.2 inches

Since the actual evapotranspiration is normally ±4 inches lower in this area than the potential, then the actual water surplus is about 10 inches per year.

We estimate that infiltration on the landfill itself may be in the order of 12 inches per year due to the relatively permeable nature of the surface. This infiltration equates to a leachate production rate of about 0.5 gallons per minute per acre. In the area of the soccer field infiltration may be in the order of 6 inches per year or 0.25 gallons per minute per acre due to the slowly permeable clay cover and grassed surface.

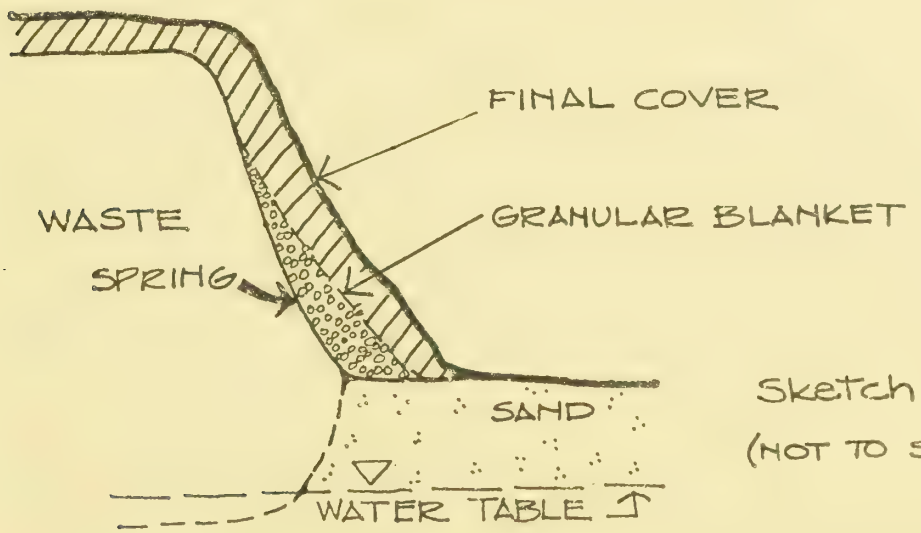
D. DISCUSSION

1. LEACHATE ASPECTS: The results of the study indicate that leachate is migrating from the wastes. The leachate, which forms from the infiltration of rain water percolating downward through the waste, enters the shallow unconfined ground water system. Flow is then outward towards Borers Creek and the pond. The pond, which was originally a wet slough at the head of Cootes Paradise is partially infilled with debris, earth and possible garbage, and for this reason the additional input of leachate has probably had a relatively small impact on the already deteriorated environment. On the other hand, leachate entering Borers Creek is probably affecting water quality based on our preliminary assessment. Although the degree of the impact appears relatively small, there may be a concern in the future due to the environmental sensitivity of the Botanical Garden lands down gradient. This matter should be discussed with the Ministry of the Environment.

Leachate springs emanating from the waste create a negative visual impact. In fact the springs may become dry during the summer months.

Control of the leachate within the ground water system will be difficult, if remedial measures are considered necessary. Certainly infiltration and thus the amount of leachate can be reduced, possibly as much as 50 percent with a clay cover 3 to 5 feet thick, site contouring to promote run-off and vegetation to increase evapotranspiration of water. Precautions will be necessary for site grading to minimize any potential for soil erosion. Once leachate enters the ground water system, the most practical approach may be to allow off-site migration at least in the short term and to monitor water quality. There are both technical and economic constraints associated with the construction of collection alternatives such as purge wells, or deep drains. A surface water monitoring station up and down gradient as well as opposite the fill might be considered to provide data for future decisions.

Since the major concern with the leachate springs at the landfill site is aesthetic, a cosmetic remedy may be justified. A toe drain system is probably not justified due to the random and discontinuous nature of these perched springs. A cosmetic solution could consist of a granular blanket hydraulically connected to the natural soils. See sketch 2 below for details.



Sketch 2
(NOT TO SCALE)

II GAS ASPECTS: Based on the results of the study and confirmed by others, there is migration of combustible gases at this landfill site. Gases, in particular methane which is combustible in air in concentrations of 5 to 15 percent, are produced in the waste. Normally the gas which is lighter than air tends to travel upward and discharges harmlessly from the landfill surface. However when the upward movement is arrested either by slowly permeable clay cover soils or frost and if the confining soils are permeable as is the situation at this facility, lateral migration occurs. The lower boundary for gas migration is the ground water table.

The presence of gas and its migration is a concern at this site. As recognized and verified by this study, methane has migrated towards and enveloped the north and east sides of the Dundas Olympic Ice Facility. There is a potential then for the concentration of gas within the structure and the subsequent danger of an explosion. Gas will also tend to follow underground services where the bedding is more permeable than the surrounding soils and thus these conduits may be a concern if they are above the zone of saturation, along with manholes and other appurtenances.

Within the soccer field, the clay cover material appears to serve as a barrier to the vertical movement of gas. However there are drainage pipes under the site which collect gas and conduct it to the discharge outlet of the pipe.

For the protection of the ice facility, a gas venting system has been suggested along the north and east sides of the structure. Further detailed hydrogeologic information such as depth of the water table, soil permeability and limits of waste are required for the proper design of a system. Permanent gas monitors would be installed around the building for purposes of the study and for future long-term observations. Conceptually,

the system should probably be constructed on Regional lands if the Region is responsible for construction and maintaince. The system would generally conform to the design suggested by Heath, with the exception that we suggest that it be an active system. Consideration should be given to the depth of the system, relative to the water table and the possible construction aspects of trenching in saturated sandy to gravelly soils. These aspects would be described in a detailed study.

Unless concern is expressed by the Ministry, the only other venting suggested is a passive system within the waste itself. However any proposed development within and adjacent to the landfill should be carefully reviewed in response to the presence of gas. This proposed development would include any enclosed structure, manhole, chamber etc.

E. CONCLUSIONS AND RECOMMENDATIONS

The study shows that the Dundas Landfill Site and the wastes disposed of in the area are generating leachate and gas and that both of these are migrating off-site.

Leachate is entering the shallow unconfined ground water system and is flowing towards the pond to the west and Borers Creek to the east. The leachate will have some degree of influence on the water quality; however the present data indicates that the impact is relatively small. There may be concern though with Borers Creek since it discharges into the environmentally sensitive Cootes Paradise. No practical or economic measures appear to be available though for the collection of this leachate, although quantities may be reduced by proper site closure measures, ie. cover and vegetation.

Gas is migrating laterally through the permeable sands and gravels, particularly from the area of the soccer field which is final covered with clay. The gas front has advanced and enveloped the north and east sides of the Dundas Olympic Ice Facility. A remedial gas venting system is necessary to protect the arena. The system should preferably be constructed on Regional lands if the Region is to assume responsibility. The design would ressemble that proposed by Heath except that the system in our opinion should be an active one. Further details are required for the detailed design of the system itself.

Based on the foregoing, we submit the following recommendations for your consideration

1. *It is recommended that a gas venting system be constructed on Regional property to protect the Dundas Olympic Ice Facility from methane gas. In this regard, a detailed hydrogeological-geotechnical study should be undertaken to provide all of the parameters for the design and construction. Details of the programme are being transmitted under separate cover for your reference.*

2. *Remedial work associated with the proper closure of the Dundas Landfill Site itself is suggested. This work should include site re-grading to promote run-off, surface erosion protection, final cover and vegetation. Some cosmetic work may also be necessary in areas of leachate springs.*

3. *All proposed development including structure, services and trenches with granular backfill etc., either on or within the environs of the waste should be carefully reviewed with respect to the gas problem.*

4. *The study findings should be reviewed by the Ministry of the Environment.*

We thank you for engaging our Firm on this study and would be pleased to discuss any aspects of the project.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED,

D.E. Jagger, P.Eng.,
Senior Project Engineer.

DEJ/hs

APPENDIX

HAND AUGER HOLES

BOREHOLE LOGS

1) William Trow Associates (Hamilton) Limited
2) Heath Survey Consultants Limited
3) Peto Associates Limited

BOREHOLE LOG SUMMARY

William Trow Assiciates (Hamilton) Ltd. November 11, 1974

BOREHOLE 1

0' 0" - 0'10"	TOPSOIL
0'10" - 8' 4"	SANDY SILT TILL - fine sand with occasional sand layers, fine to coarse gravel, clayey, red shale fragments, brown, moist to very moist, dense.
8' 4" - 23' 4"	SILTY CLAY TILL - cohesive, fine gravel throughout, oxidized brown becoming grey below 12' depth, very moist, very stiff to stiff below 12' depth.
	PIEZOMETER AT 20'10" WATER LEVEL AT 8'4"

BOREHOLE 2

0' 0" - 4' 0"	FILL - fine sand, silty, organic, gravel, brown moist, compact.
4'10" - 11' 0"	SAND AND GRAVEL - fine to coarse silty, sand layers, slightly clayey near 10' depth, brown moist becoming wet near 10½' depth, dense to very dense.
11' 0" - 21' 6"	SILTY CLAY TILL - cohesive, fine gravel throughout, slightly layered with silt partings, grey very moist, very stiff.
	WATER LEVEL AT 10'0"

BOREHOLE 3

0' 0" - 4' 4"	FILL - fine sand, silty, organic, gravel sizes, brown, very moist, compact.
4' 4" - 6' 4"	SANDY SILT TILL - fine sand with fine to coarse gravel, brown, moist, very dense.
6' 4" - 12' 4"	SAND - fine sand, silt layers, oxidized brown, very moist, wet, compact.
12' 4" - 22' 6"	SILTY CLAY TILL - cohesive, some fine sand, fine gravel, grey, very moist, stiff.
	WATER LEVEL AT 10'4"

BOREHOLE 4

0' 0" - 0' 7"	TOPSOIL
0' 7" - 3' 1"	SANDY SILT - some organics, dark brown, moist.
3' 1" - 15' 7"	SAND AND GRAVEL - fine to coarse, silty, sand layers, brown, moist becoming wet near 13½' depth, compact to very dense.
15' 7" - 23'	SILTY CLAY TILL - cohesive, slightly layered, silt partings, fine gravel, grey, very moist, very stiff.
	WATER LEVEL AT 13'7"

BOREHOLE LOG SUMMARY

Heath Survey Consultants Ltd. January, 1979.

BOREHOLE 1

0' 0" - 2' 0"	FILL - granular 'A' fill material.
2' 0" - 6' 0"	SANDY SILT TILL - oxidized brown sandy silt till.
6' 0" - 9' 0"	SILTY CLAY TILL - stiff, grey brown silty clay till.
	COMBUSTIBLE GAS 2.5%
	HOLE DRY

BOREHOLE 2

0' 0" - 2' 0"	FILL - granular 'A' fill material.
2' 0" - 6' 0"	SANDY SILT TILL - oxidized brown sandy silt till.
	COMBUSTIBLE GAS 1.5%
	HOLE DRY

BOREHOLE LOG SUMMARY

Peto Associates Ltd. January, 1973

BOREHOLE 12

0' 0" - 0'10"	TOPSOIL
0'10" - 9' 0"	SILT - medium brown, slightly clayey silt, grits, wet.
9' 0" - 10' 0"	GRAVELLY SAND - wet
	HOLE DRY

BOREHOLE 13

0' 0" - 0'10"	TOPSOIL
0'10" - 10' 0"	SILT - medium brown slightly clayey silt, grits, wet
	HOLE DRY

BOREHOLE 14

0' 0" - 1' 0"	FILL - sandy silt fill, moist
1' 0" - 18' 0"	ORGANIC GARBAGE - cloth, wire mixed with sandy gravel - mostly wet sandy silt from 12'
18' 0" - 20' 0"	GRAVELLY SAND - reddish brown, moist
	HOLE DRY

BOREHOLE 15

0' 0" - 2' 0"	FILL - sandy gravel to gravelly sand, fine moist to saturated
2' 0" - 13' 0"	ORGANIC GARBAGE - cloth, wire, mixed with grey sandy gravel, saturated
13' 0" - 15' 0"	GRAVEL
	HOLE CAVED TO 4'10" - NO WATER

BOREHOLE 16

0' 0" - 5' 0"	FILL - dark brown sandy gravel fill, moist, becoming sandy silt with depth
5' 0" - 7' 0"	GRAVELLY SAND - grey gravelly sand, saturated
	HOLE CAVED TO 6'6" - NO WATER

BOREHOLE 17

0' 0" - 4' 0"	FILL - sandy gravel fill, boulders, moist
4' 0" - 6' 0"	ORGANIC GARBAGE - moist
6' 0" - 10' 0"	GRAVELLY SAND - medium brown, gravelly sand, moist
	HOLE CAVED TO 8'0" - NO WATER

BOREHOLE 18

0' 0" - 3' 6"	FILL - gravelly silty sand fill, moist
3' 6" - 16' 0"	ORGANIC GARBAGE - cloth, paper - mixed with sand and gravel and saturated below 12'
16' 0" - 17' 0"	SILTY CLAY - wetter than plastic limit
	HOLE CAVED TO 11'6" - NO WATER

BOREHOLE 20

0' 0" - 4' 0"	FILL - dark brown, gravelly sandy silt fill, boulders, moist
4' 0" - 6' 0"	SANDY GRAVEL - red brown, sandy gravel, moist
6' 0" - 8' 0"	GRAVELLY SAND - brown grey gravelly sand, saturated
8' 0" - 12' 0"	SILTY CLAY - grey silty clay, wetter than plastic limit
	HOLE CAVED TO 5'6" - NO WATER

BOREHOLE 21

0' 0" - 7' 0"	SANDY GRAVEL - medium brown, silty sandy gravel, moist
7' 0" - 10' 0"	SILTY CLAY - grey silty clay, at plastic limit
	HOLE DRY

BOREHOLE 22

0' 0" - 0' 8"	TOPSOIL
0' 8" - 3' 6"	SANDY GRAVEL - dark, reddish brown silty sandy gravel, moist
3' 6" - 17' 0"	SANDY GRAVEL- reddish to medium brown sandy gravel, moist
17' 0" - 20' 0"	SILTY CLAY - grey silty clay, grits and pebbles, wetter than plastic limit
	HOLE DRY

HAND AUGER HOLES

DUNDAS LANDFILL SITE
MAY 28, 1979

HAND AUGER HOLE 1

0'0" - 4'0"	Medium brown, moist, silty pebbly fine sand fill- a few brick pieces. Combustible gas - 5%

HAND AUGER HOLE 2

0'0" - 0'1"	Grey, dry, ¼" crushed stone fill.
0'1" - 4'6"	Red brown, moist, silty pebbly fine sand fill becomes wetter and slightly siltier below 3'0". Combustible gas - 15%

HAND AUGER HOLE 3

0'0" - 5'0"	Medium brown, moist silty pebbly fine sand. Becomes red brown, softer, wetter, and slightly siltier below 2'0". Combustible gas - 0%.

HAND AUGER HOLE 4

0'0" - 0'6"	Dark brown, moist, silty sand topsoil.
0'6" - 5'0"	Red brown, moist, slightly silty sand-occasional pebble. Becomes softer, wetter siltier and contains slightly more fine gravel with increasing depth. Combustible gas - 25%.

HAND AUGER HOLE 5

0'0" - 1'0"	Dark brown, moist, silty topsoil.
1'0" - 1'6"	Medium brown, moist, sandy silt.
1'6" - 3'0"	Red brown, moist sandy silt-occasional pebble.
3'0" - 3'6"	Red brown, moist, silty pebbly fine sand- occasional stones. Refusal at 3'6" on stone. Combustible gas - 0%.

HAND AUGER HOLE 6

0'0" - 1'6"	Dark brown, moist, silty topsoil.
1'6" - 3'6"	Red brown, moist, slightly silty fine sand.
3'6" - 4'0"	Red brown, wet, fine sand.
4'0" - 5'0"	Red brown, moist to wet, silty fine sand. Combustible gas - 0%.

HAND AUGER HOLE 7

0'0" - 0'6"	Dark brown, moist, silty topsoil.
0'6" - 3'0"	Medium to light brown, moist, silty very fine sand.
3'0" - 4'6"	Red brown, moist, slightly sandy silt
4'6" - 5'0"	Red brown, moist, silty pebbly fine to medium sand. Combustible gas - 0%.

HAND AUGER HOLE 8

0'0" - 0'6"	Dark brown, moist, silty topsoil.
0'6" - 4'6"	Red brown, moist, slightly silty pebbly fine to medium sand - occasional stone. Becomes wetter and slightly siltier below 4'0". Refusal at 4'6" on stone. Combustible gas - 0%.

HAND AUGER HOLE 9

0'0" - 0'5"	Dark brown, moist, silty sand topsoil.
0'5" - 5'0"	Red brown, moist, slightly silty pebbly fine to medium sand. Becomes wetter and slightly siltier below 3'6". Occasional stone. Combustible gas - 0%.

HAND AUGER HOLE 10

0'0" - 0'6"	Dark brown, moist, silty sand topsoil.
0'6" - 3'0"	Red brown, moist, slightly silty pebbly fine to medium sand - occasional stone. Refusal at 3'0" on stone. Combustible gas - 0%.

HAND AUGER HOLE 11

0'0" - 1'0"	Dark brown, moist, silty topsoil.
1'0" - 2'0"	Red brown, moist, silty pebbly fine sand - occasional stone. Refusal at 2'0" on stone. Combustible gas - 0%.

HAND AUGER HOLE 12

0'0" - 0'6"	Dark brown, sandy silt topsoil.
0'6" - 3'0"	Red brown, moist, silty pebbly sand - occasional stone. Refusal at 3'0" on stone. Combustible gas - 0%.

HAND AUGER HOLE 13

0'0" - 0'6"	Dark brown, moist, silty sand topsoil.
0'6" - 4'0"	Red brown, slightly silty, pebbly fine to medium sand. Wetter, softer and slightly siltier from 2'0" - 3'0". No silt below 3'0". Combustible gas - 0%.

HAND AUGER HOLE 14

0'0" - 0'6"	Brown, moist, silt (Pond siltation).
0'6" - 1'0"	Dark brown, sandy silt fill - slight rank smell.
1'0" - 2'0"	Black, moist silty refuse (Paper, wood, glass, plastic, construction rubble) - rank smell. Refusal at 2'0" on rubble. Combustible gas - 48%.

HAND AUGER HOLE 15

0'0" - 0'6"	Brown, moist, pebbly silt fill.
0'6" - 2'0	Grey, moist silt fill.
2'0" - 2'6"	Black, moist silty refuse (Paper, wood, rags, construction rubble) - rank smell.
2'6" - 3'6"	Black, moist silt fill. Saturated at 3'0". Combustible gas - 5% (Gas bubbling in hole).

HAND AUGER HOLE 16

0'0" - 0'2"	Saturated organic mat (Plant leaves and roots-slightly decayed).
0'2" - 5'0"	Brown to brown grey, saturated clayey silt. Combustible gas - 0%.

HAND AUGER HOLE 17

0'0" - 1'6"	Grey, moist, clayey slightly pebbly silt fill (Some wood and paper mixed in).
1'6" - 4'0"	Grey brown to brown, wetter than plastic limit, clayey silt. Saturated below 2'6". Combustible gas - 0.5%.

HAND AUGER HOLE 18

0'0" - 1'0"	Brown, moist slightly sandy, pebbly silt fill.
1'0" - 2'3"	Grey, moist, irregularily stratified silt fill - Rank smell.
2'3" - 3'6"	Black, moist with the occasional wet zone, sandy refuse (Paper, wood, rags, construction rubble) - rank smell. Refusal at 3'6" on construction rubble. Combustible gas - 57% (Slight positive pressure).

HAND AUGER HOLE 19

0'0" - 2'0"	Brown, moist, pebbly silt fill - some paper mixed in.
2'0" - 3'6"	Black, moist silty refuse (Plastic, rags, paper, leaves, wood, construction rubble) - rank smell. Saturated at 3'0". Combustible gas - 11%.

HAND AUGER HOLE 20

0'0" - 3'0"	Light grey, moist, clayey silt fill.
3'0" - 4'0"	Red brown, moist, slightly silty pebbly sand. Occasional stone. Refusal at 4'0" on stone. Combustible gas - 0%.

HAND AUGER HOLE 21

0'0" - 0'8"	Light grey, moist, clayey silt fill.
0'8" - 6'0"	Red brown, moist, slightly silty, pebbly sand. Stony at 3'0". Combustible gas - 0%.

HAND AUGER HOLE 22

0'0" - 1'0"	Medium brown, moist, silty sand fill - a few pebbles.
1'0" - 2'6"	Red brown, moist, slightly silty, pebbly sand - occasional stone. Combustible gas - 0%.

HAND AUGER HOLE 23

0'0" - 0'6"	Medium brown, moist, slightly silty, pebbly fine to medium sand fill.
0'6" - 1'0"	Medium brown, moist, sandy silt fill.
1'0" - 2'0"	Dark grey, moist, mixed silty fill - rank smell.
2'0" - 5'6"	Medium brown, moist, slightly pebbly, fine to medium clean sand. Stone at 3'0". Grading to fine sand below 3'10". Combustible gas - 32%.

HAND AUGER HOLE 24

0'0" - 0'8"	Medium brown, moist, slightly silty and pebbly, sand fill.
0'8" - 2'0"	Dark grey to black, moist silt fill with refuse (Paper, glass, wood, plastic, construction rubble). Refusal at 2'0" on rubble. Combustible gas - 8%.

HAND AUGER HOLE 25

0'0" - 2'6"	Grey, moist, sandy silt.
2'6" - 4'0"	Dark grey, moist, silt fill with refuse (Paper, wood).
4'0" - 6'0"	Medium brown, moist, slightly silty fine sand. Becomes slightly siltier and wetter below 5'0". Combustible gas - 48%

HAND AUGER HOLE 26

0'0" - 2'0"	Medium brown, moist, slightly pebbly sandy silt fill. Refusal at 2'0" on stone. Combustible gas - 0%.

HAND AUGER HOLE 27

0'0" - 0'3"	Medium brown, saturated, clayey silt fill.
0'3" - 0'9"	Black, wet silty refuse.
0'9" - 4'0"	Grey, moist, clayey silt fill.
4'0" - 5'0"	Medium brown, moist to wet, fine sand.
5'0" - 6'0"	Medium brown, saturated, pebbly clean fine to coarse sand. Combustible gas - 50%.

HAND AUGER HOLE 28

0'0" - 2'0"	Medium brown, moist pebbly fine to medium sand. Refusal at 2'0" on stone. Combustible gas - 8%.

HAND AUGER HOLE 29

0'0" - 1'0"	Light brown, moist, slightly pebbly silty sand fill.
1'0" - 4'0"	Red to red brown, moist, pebbly fine to medium sand. Slight rank smell. Combustibe gas - 24%.

HAND AUGER HOLE 30

0'0" - 3'0"	Medium brown, saturated, slightly silty pebbly fine to medium sand. Becomes dark grey with a slight rank smell from 1'0" to 1'6". Combustible gas - 30%.

HAND AUGER HOLE 31

0'0" - 0'6"	Dark brown, silty topsoil.
0'6" - 4'0"	Red brown, moist, silty pebbly fine sand. Combustible gas - 30%.

HAND AUGER HOLE 32

0'0" - 0'6"	Black, saturated silty fill.
0'6" - 4'0"	Red brown, moist, silty pebbly fine sand. Stones throughout. Combustible gas - 30%.

HAND AUGER HOLE 33

0'0" - 4'0"	Red brown, moist silty, pebbly and stony sand fill.
4'0" - 6'0"	Red brown, moist, slightly silty, pebbly and stony fine to medium sand.
6'0" - 6'6"	Medium brown, wetter than plastic limit, clayey silt. Saturated below 5'0". Combustible gas - 0%.

HAND AUGER HOLE 34

0'0" - 4'0"	Red brown, moist, slightly silty pebbly and stony fine to medium sand fill. Combustible gas - 0%.

HAND AUGER HOLE 35

0'0" - 0'6"	Medium brown, moist, silty sand fill - some stones.
0'6" - 6'0"	Red brown, moist, pebbly fine to medium sand fill. Combustible gas - 22%.

HAND AUGER HOLE 36

0'0" - 0'6"	Dark brown, moist, silty topsoil fill.
0'6" - 1'2"	Grey, moist silty clay fill.
1'2" - 2'6"	Red brown, moist, silty, pebbly fine to medium sand fill.
2'6" - 3'6"	Medium brown, moist, clayey silt fill - small pieces of brick throughout. Refusal at 3'6". Combustible gas - 4.5%.

HAND AUGER HOLE 37

0'0" - 4'6"	Medium brown, moist, slightly stony silt sand fill.
4'6" - 5'0"	Dark brown, moist, silty topsoil.
5'0" - 5'6"	Red brown, moist, slightly silty pebbly fine to medium sand. Combustible gas - 30%.

HAND AUGER HOLE 38

0'0" - 0'8"	Red brown, moist, silty pebbly and stony sand fill.
0'8" - 6'0"	Light brown, wetter than plastic limit, silty clay fill. Combustible gas - 0%.

HAND AUGER HOLE 39

0'0" - 0'6"	Medium brown, moist, slightly silty, pebbly fine to medium sand fill.
0'6" - 4'0"	Dark grey to brown, very dense, moist, well mixed, slightly sandy clayey silt fill. Combustible gas - 1%.

HAND AUGER HOLE 40

0'0" - 2'0"	Red brown, moist, slightly silty, pebbly and stony fine to medium sand fill.
2'0" - 3'0"	Light brown, moist, clayey silt fill.
3'0" - 4'0"	Black, saturated, soft organics. Combustible gas - 7%.

HAND AUGER HOLE 41

0'0" - 1'0"	Red brown, moist, slightly silty, pebbly and stony sand fill.
1'0" - 3'8"	Red, moist, clayey silt fill.
3'8" - 4'0"	Black, moist silty refuse (Wood, paper). Combustible gas - 6%.

HAND AUGER HOLE 42

0'0" - 2'6"	Grey, very dense, moist, clayey silt fill. Occasional pebble.
2'6" - 3'0"	Light brown, moist, slightly sandy silt.
3'0" - 4'0"	Medium brown, moist, slightly silty fine sand. Combustible gas - 7%.

HAND AUGER HOLE 43

0'0" - 2'0"	Medium brown, moist clayey silt.
2'0" - 4'0"	Medium brown, moist, pebbly fine sand. Combustible gas - 0%.

HAND AUGER HOLE 44

0'0" - 1'0"	Light brown, moist, pebbly clayey silt fill.
1'0" - 2'0"	Red brown, moist, slightly silty, pebbly and stony sand fill. Refusal at 2'0" on stone. Combustible gas - 0%.

HAND AUGER HOLE 45

0'0" - 2'0"	Red brown, moist, silty, pebbly and stony fine sand fill.
2'0" - 2'6"	Black, moist, silty refuse.
2'6" - 4'0"	Grey brown, very dense wetter than plastic limit, slightly sandy clayey silt. Saturated below 3'6". Combustible gas - 2.5%

HAND AUGER HOLE 46

0'0" - 3'0"	Grey, very dense, wetter than plastic limit, pebbly, silty clay fill. Becomes brown in colour below 1'6". Occasional stone. Refusal at 3'0" on stone. Combustible gas - 0%.

HAND AUGER HOLE 47

0'0" - 1'0"	Red brown, moist, slightly silty, pebbly sand fill.
1'0" - 3'6"	Grey to grey brown, very dense, moist, clayey silt fill. Some sand mixed in below 2'6". Combustible gas - 0%.

HAND AUGER HOLE 48

0'0" - 0'8"	Red brown, moist, silty sand fill.
0'8" - 3'6"	Grey, very dense, moist, clayey silt fill. Combustible gas - 1.5%.

HAND AUGER HOLE 49

0'0" - 0'4"	Dark brown silty topsoil fill.
0'4" - 4'0"	Red brown, moist, slightly silty pebbly sand. Combustible gas - 0%.

HAND AUGER HOLE 50

0'0" - 3'0"	Dark brown, moist, pebbly, sandy silt fill. Occasional stone. Refusal at 3'0" on stone. Combustible gas - 0%.

HAND AUGER HOLE 51

0'0" - 2'6"	Black, wet, silty fill with refuse (Paper, rubble). Rank smell. Refusal at 2'6" Combustible gas - 0.5%.

HAND AUGER HOLE 52

0'0" - 3'6"	Medium brown, damp silty pebbly sand fill. Moist to wet below 2'0". Slight odour. Becoming coarser below 2'6". Combustible gas - 3.5%.

HAND AUGER HOLE 53

0'0" - 1'6"	Medium brown, moist silty pebbly and stony sand fill. Refusal at 1'6" on stone. Combustible gas - 0%.

HAND AUGER HOLE 54

0'0" - 4'0"	Medium brown to grey brown, moist, silty pebbly sand fill. Becomes coarser below 1'6". Combustible gas - 10%.

HAND AUGER HOLE 55

0'0" - 2'0"	Dark brown, moist, silt.
2'0" - 2'6"	Red brown, moist sandy silt.
2'6" - 4'0"	Red brown, wet pebbly, sandy silt. Combustible gas - 0.5%.

HAND AUGER HOLE 56

0'0" - 3'0"	Red brown, moist, pebbly and stony silty sand fill. Becomes slightly sandier below 2'0". Combustible gas - 0%.

HAND AUGER HOLE 57

0'0" - 2'0"	Red brown, moist, pebbly and stony silty sand fill. Refusal at 2'0" on stone. Combustible gas - 0%.

HAND AUGER HOLE 58

0'0" - 2'0"	Red brown, wet, pebbly and stony silty sand fill. Becomes moist with less silt below 1'0". Refusal at 2'0" on stone. Combustible gas - 0%.

HAND AUGER HOLE 59

0'0" - 1'0"	Brown, moist, pebbly silt fill.
1'0" - 1'6"	Grey, moist, silty fill. Rank smell.
1'6" - 3'0"	Black, moist silty refuse (Paper, wood, plastic, construction rubble). Rank smell. Combustible gas - 43%.

TABLE 1

WATER BUDGET SUMMARY
(AVERAGE)

MONTH	MEAN PRECIPITATION (inches)	POTENTIAL EVAPOTRANSPIRATION (inches)	WATER EXCESS (inches)	WATER DEFICIT (inches)
January	2.23	0	2.23	
February	2.38	0	2.38	
March	2.78	0	2.78	
April	2.72	1.32	1.40	
May	3.09	2.88	.21	
June	2.37	4.70		2.33
July	2.97	5.59		2.62
August	2.95	4.96		2.01
September	2.47	3.19		.72
October	2.54	1.83	.71	
November	2.39	.54	1.85	
December	2.33	0	2.33	
	31.22	25.01	13.89	7.68

NOTE: Climatological Station Location in Hamilton
Latitute 43^{0} 16' N, Longitude 79^{0} 54' W
Elevation 303' ASL